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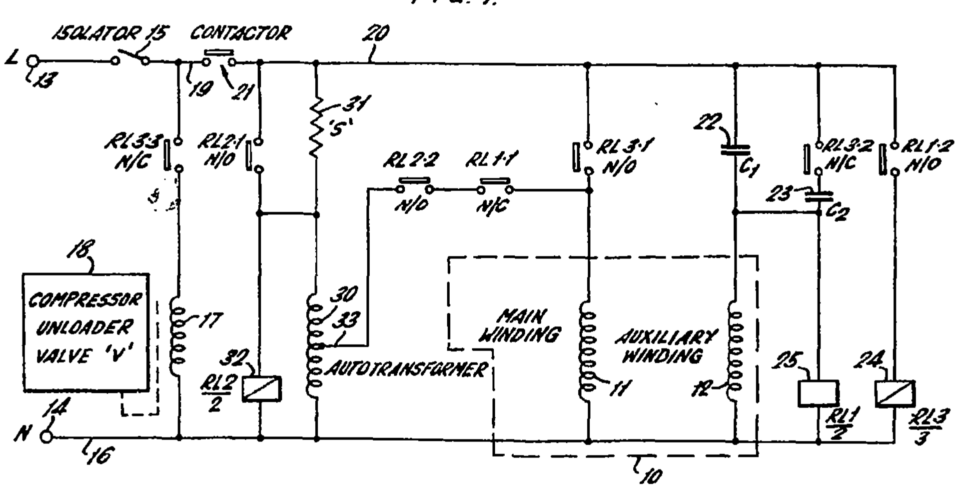
(54) A starting circuit for a single-phase induction motor

(57) The motor has a main winding 11 and an auxiliary winding 12 with capacitor means 22, 23 and the starting circuit is provided with circuit means operative on starting the motor to reduce the voltage on the main winding, preferably by use of an autotransformer 30, a tapped portion of which is switched into circuit with the main winding on initial starting so that the voltage on the main winding is of lower magnitude than the normal running voltage. A relay 25 across the auxiliary winding controls switch means with a delay (relay 32) to apply the full voltage to the main winding as the motor runs up to speed.

FIG. 1.



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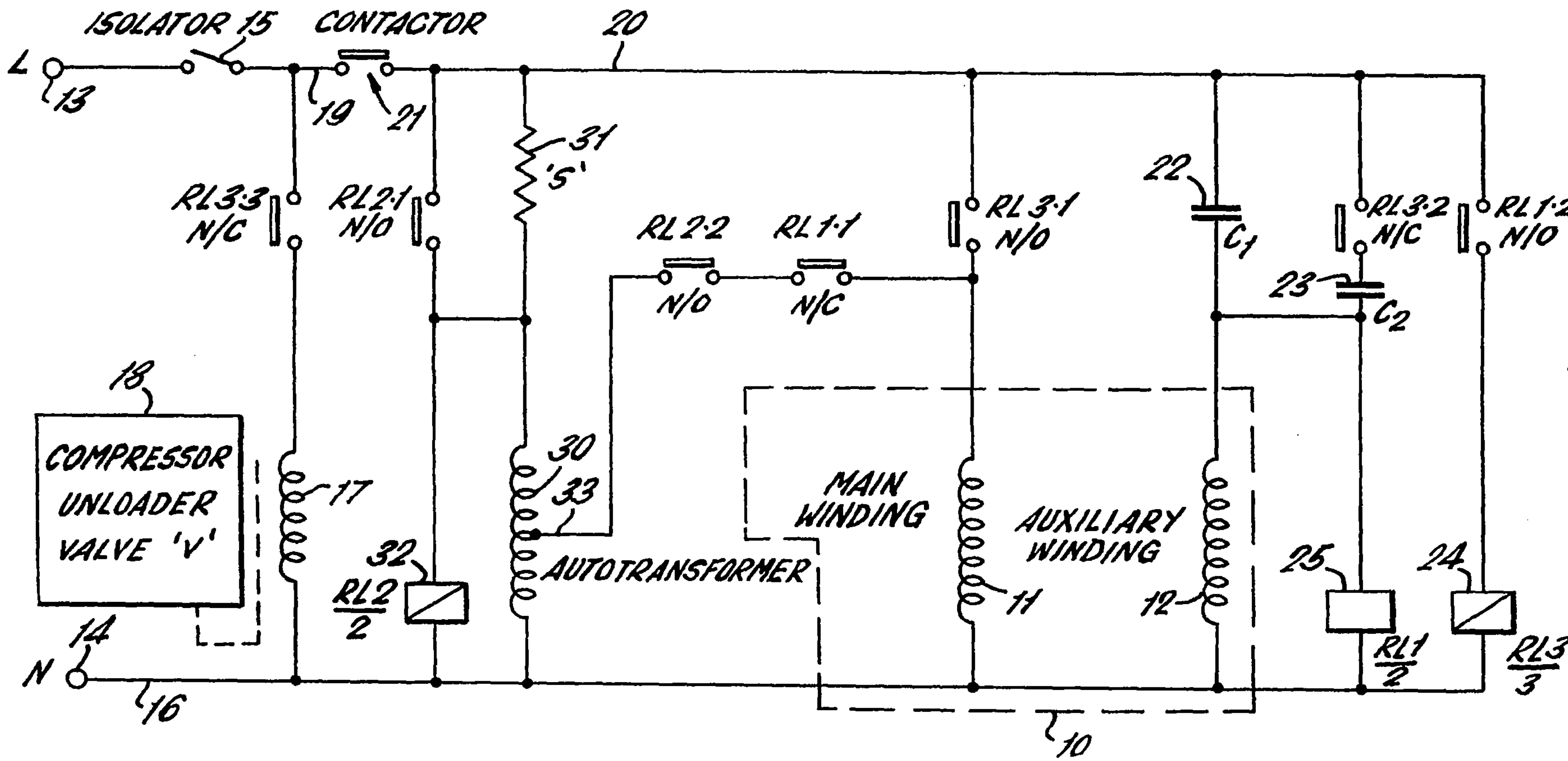
The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.

FIG. 1.



L
13
ISOLATOR 15
CONTACTOR
19
21
20
RL3:3 N/C
RL2:1 N/O
31
'S'
RL2:2 N/O
RL1:1 N/C
RL3:1 N/O
22
C1
RL3:2 N/C
23
C2
RL1:2 N/O
18
COMPRESSOR UNLOADER VALVE 'V'
17
32
RL2 2
30
33
AUTOTRANSFORMER
MAIN WINDING
AUXILIARY WINDING
11
12
25
RL1 2
24
RL3 3
14
N
16
10

FIG. 2.

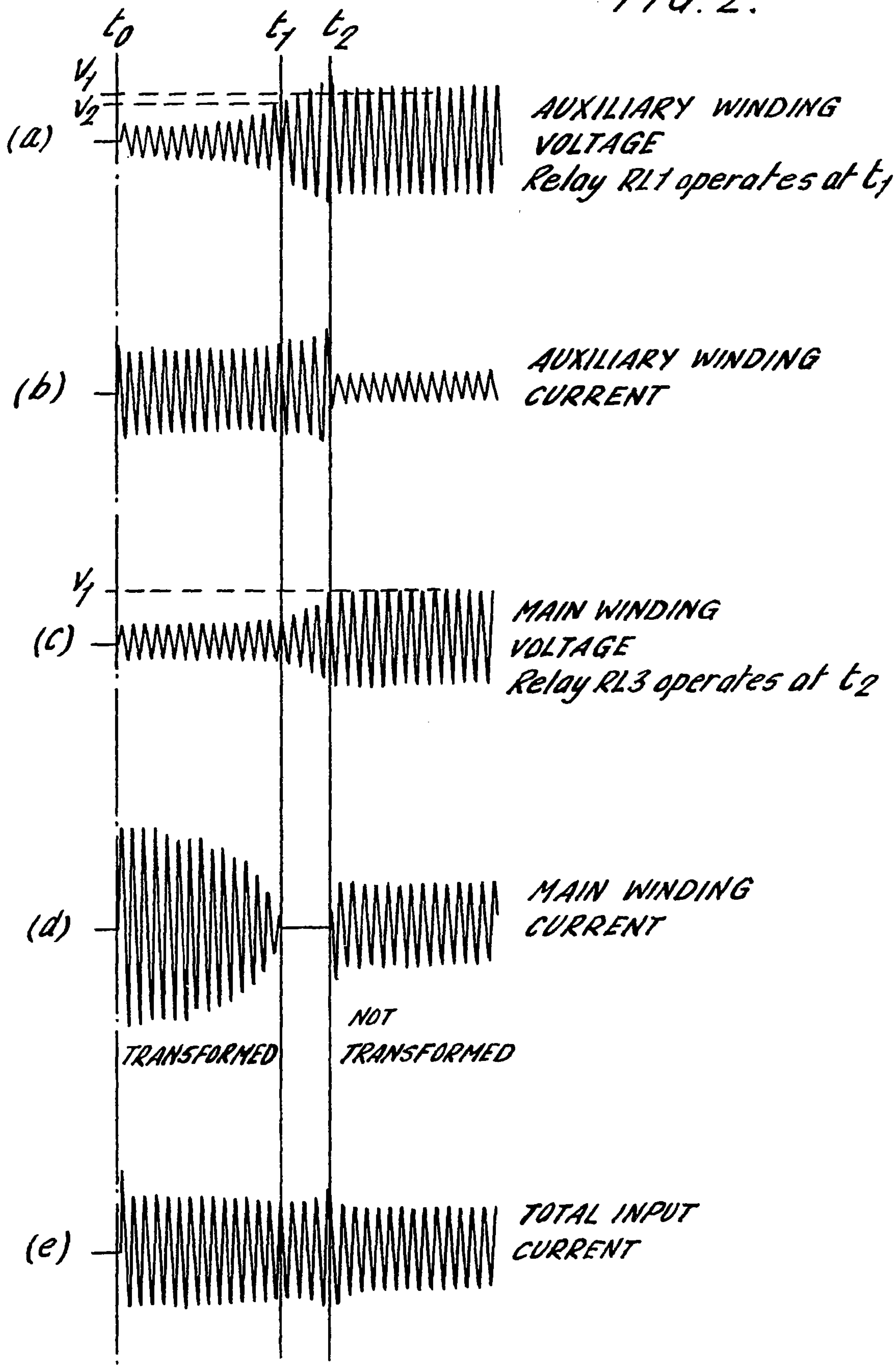
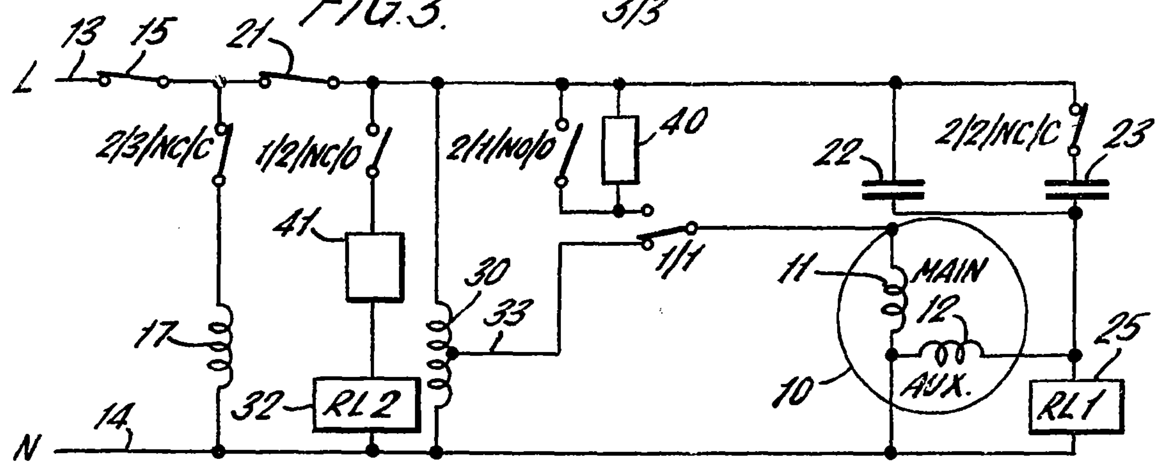

t_0
t_1
t_2
V_1
V_2
(a)
AUXILIARY WINDING VOLTAGE
Relay RL1 operates at t_1
(b)
AUXILIARY WINDING CURRENT
V_1
(c)
MAIN WINDING VOLTAGE
Relay RL3 operates at t_2
(d)
MAIN WINDING CURRENT
TRANSFORMED
NOT TRANSFORMED
(e)
TOTAL INPUT CURRENT

FIG.3.


L
13
15
21
2/3/NC/C
1/2/NC/O
2/1/NO/O
40
22
2/2/NC/C
23
41
1/1
30
33
11
MAIN
12
17
AUX.
25
10
32
RL2
RL1
N
14

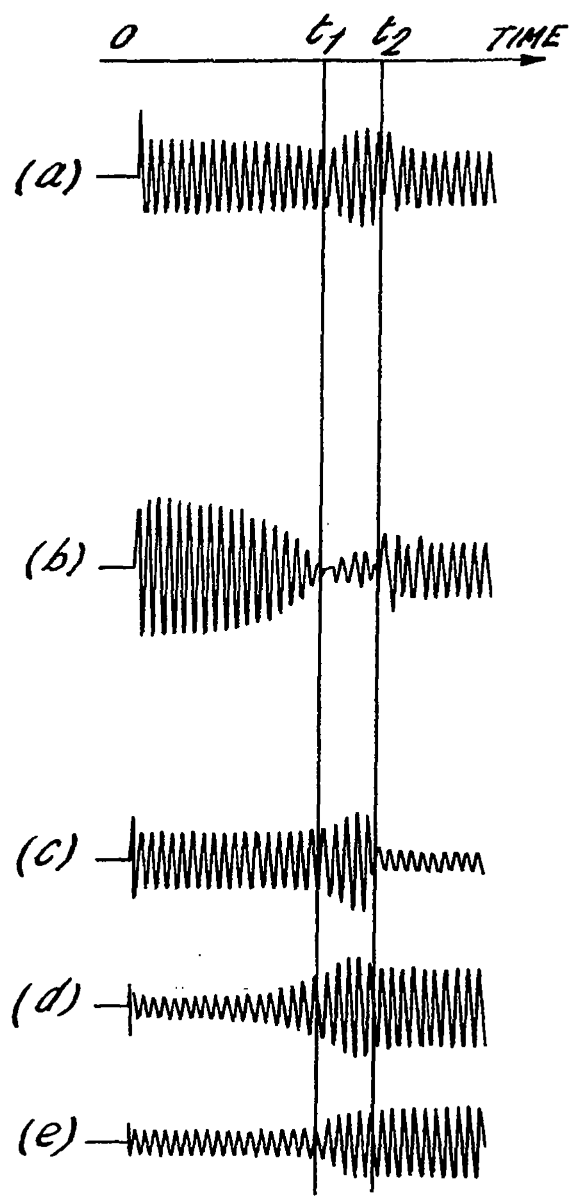

0
t_1
t_2
TIME
(a)
(b)
(c)
(d)
(e)

FIG.4.

SPECIFICATION

Starting circuits for single phase induction motors

This invention relates to starting circuits for direct on-line starting to single phase induction motors.

It is well-known that, when direct on-line starting is used for a single phase induction motor, the current drawn from the power supply is, for a significant number of cycles, considerably greater than the full load current when the motor is running. The maximum starting current might typically be four to eight times the magnitude of the normal full load current. The large current surge on starting an induction motor in this way can produce a voltage dip on the electricity supply distribution network and hence may interfere with other consumers.

For starting a single phase induction motor such as might be used for driving a compressor in a refrigerator or heat pump, it is known to provide the motor with an auxiliary winding as well as the main winding, the auxiliary winding being connected, in series with a first capacitor across the main winding and hence across the supply and to provide, in shunt across the first capacitor, a second capacitor in series with a normally closed switch which switch is opened as the motor runs up to speed. The auxiliary winding with its capacitive feed giving a quadrature current enables the motor to self-start. Although primarily for starting, the auxiliary winding may be supplied with a small capacitive current while the motor is running to enhance the torque/speed characteristic. For this reason the two capacitors and the switch are provided. The opening of the switch may be effected automatically by using, as this switch, a contact on a relay connnected in shunt across the auxiliary winding. With such a circuit, when the motor is first energised, the main winding is connected across the supply circuit and, in addition the two capacitors, in parallel with one another, are in series with the auxiliary winding so that this auxiliary winding is energised through the capacitor thereby increasing the starting torque. As the motor runs up to speed, the voltage across the auxiliary winding will increase, and can increase to a voltage greater than the applied voltage, and the relay may be arranged so that, when this voltage across the winding reaches some predetermined value, e.g. 80%, of the applied voltage, the relay operates so as to disconnect the second capacitor. It will be seen that such a circuit provides the required starting torque but draws the large surge current referred to previously. This high starting current arises primarily because, while the motor is starting or running slowly, the back e.m.f. in the main winding is low and the current is restricted only by the impedance of the motor. When the motor is running near full speed, the winding e.m.f. is high and the current low.

It is an object of the present invention to provide an improved form of starting circuit for an induction motor which reduces the surge current on starting.

According to the present invention, a starting circuit for a single phase induction motor having a main winding and an auxiliary winding with capacitor means in series with the auxiliary winding to provide a current therethrough on energising th starting circuit, has in addition circuit means operative on starting the motor to reduce the voltage on the main winding to a lower magnitude than the normal running voltage, with switch means operative to apply the full voltage to the main winding as the motor runs up to speed. Additionally, means may be provided, operative on starting the motor, to disconnect or reduce the load on the motor until the full voltage is applied to the main winding.

It will be seen that, with this starting circuit, the auxiliary winding is energised by the capacitive means to provide extra starting torque. The reduction in voltage applied to the main winding however reduces the starting current. The magnitude of the required starting torque however can be substantially reduced, in the preferred arrangement, by the disconnection or reduction of the mechanical load on the motor until the motor runs up to speed. The voltage applied to the main winding is conveniently effected by energising the main winding via a transformer or auto transformer with switch means, e.g. a relay, operative to switch out the direct energising circuit from the mains until the motor runs up to speed. The voltage across the auxiliary winding builds up slowly in the known manner and a relay or other switching device may be provided connected across this auxiliary winding and operative when the voltage across that winding has reached some predetermined value to effect the necessary switching directly or indirectly. This relay may be arranged for example to disconnect the main winding from the autotransformer and, after a delay, to effect connection to the power supply.

Preferably therefore there is provided first relay responsive to the voltage across the auxiliary winding and arranged to disconnect the main winding from the transformer and to energise a further relay which operates, after a delay, to connect the main winding to the mains supply and to connect the mechanical load to the motor to be driven thereby. This further relay may also be arranged to disconnect a capacitor in series with the auxiliary winding.

Conveniently the aforementioned transformer is an auto-transformer with its winding, in series with a surge prevention resistor, connected across the power supply input. Prefera-

bly a delayed operation switching device, e.g. a relay, is provided responsive to the voltage across the auto-transformer with contact means operative to short-circuit the surge resistor after a short delay. This is to suppress a surge in the current due to the requirement for energising the transformer. This delayed action switching device may be arranged to complete the circuit for energising the main winding from the auto-transformer at a short time after the auto-transformer is energised. When the transformer is of such a type that the surge in the current due to the requirements for energising the transformer is sufficiently low to be not disadvantageous then the surge prevention resistor and that delayed operation switching device would not be included.

It would be possible to reduce the voltage on the main winding by connecting a resistor in series therewith. As explained later, it is preferred to employ, however, a transformer or auto-transformer.

Instead of connecting the main winding directly to the mains supply with a delay after it is disconnected from the transformer, it may be preferred to connect the main winding temporarily to the mains supply via a thermistor to provide a small current. This enables the main winding e.m.f. to rise to a larger value after switching from the transformer, before the full mains supply voltage is applied.

The following is a description of two embodiment of the invention, reference being made to the accompanying drawings in which:—

Figure 1 is a circuit diagram of a starting circuit for a single phase induction motor, the diagram including the main winding and auxiliary winding of the motor;

Figures 2a, b, c, d and e are diagrams illustrating current and voltage waveforms at the motor and the total current input from the supply in the embodiment of Fig. 1;

Figure 3 is a circuit diagram of a second embodiment of the invention; and

Figures 4a, b, c, d and e are diagrams illustrating current and voltage waveforms of the motor and the total supply current input for the embodiment of Fig. 3.

Referring to Fig. 1 there is shown diagrammatically, as a box 10, a single phase induction motor, there being shown within this box a main winding 11 and an auxiliary winding 12, these being the parts of the motor to which specific reference will be made in describing the circuit for starting the motor. The circuit is energised from a mains power supply source indicated by live terminal 13 and neutral terminal 14 of an alternating current mains supply. In series with the lead from terminal 13 is an isolator 15 for electrically isolating from a lead 19 in the circuit, which lead, when the isolator is closed, constitutes the "live" lead. Connected in shunt between the lead 19 and a line 16 connected to the neutral terminal 14 is a circuit comprising a normally closed contact RL3.3 of a relay RL3 to be described later in series with an operating coil 17 of an electro-mechanical unloader 18 for reducing or disconnecting the load on the motor. The motor 10 might typically be employed to drive a compressor of a heat pump or refrigerator and, in such a case, the unloader 18 may be arranged mechanically to operate to disconnect the load from the motor so long as relay contact RL3.3 remains closed. The load will be connected to the motor when the relay contact RL3.3 is opened in a manner to be described later.

Power for the motor and starter circuit is obtained from supply leads comprising a neutral lead and a lead 20 which can be connected by a contactor 21 to the aforementioned lead 19 and hence, via isolator 15, to the live terminal 13. The main winding 11 of the motor 10 is connected in series with a normally open contact RL3.1 of relay RL3, the series circuit of winding and relay contact being in shunt between the leads 16 and 20, with the winding 11 being between the relay contact and the lead 16. The auxiliary winding 12 in series with a capacitor 22 is also arranged across the leads 16 and 20, the winding 12 being connected between lead 16 and the capacitor 22. The capacitor 22 is shunted by a circuit comprising a second capacitor 23 and a normally closed contact RL3.2 of the relay RL3. The relay RL3 may be an electromechanical relay but, as described later, is preferably a solid-state switching device. An operating circuit 24 of relay RL3, in series with a normally open contact RL1.2 of a relay RL1, is also connected between the leads 16 and 20. Relay RL1, which may be electro-mechanical or a solid-state switching device, has an operating circuit 25 connected in shunt across the auxiliary winding 12. The relay RL1 is a relay which operates when the voltage across the winding 12 reaches some predetermined value, for example 80% of the applied voltage. The voltage across the auxiliary winding, after the contactor 21 is closed, (assuming isolator 15 is already closed) will rise slowly because of the series impedance and the waveform of this voltage is shown in Fig. 2a which is a waveform diagram showing the voltage plotted against time. The full mains voltage is shown in V1. Switching on occurs at time zero and the relay RL1 operates when the voltage level has reached V2, that is to say at a time t1. During this time period, the relay RL3 remains unoperated and hence contact RL3.2 remains closed and thus the winding 12 is in series with both capacitors 22 and 23.

Connected in shunt between the leads 20 and 16 is an auto-transformer 30 in series with a surge resistor 31. In shunt across the

auto-transformer winding is an operating circuit 32 of a relay RL2 which may be an electro-mechanical or a solid-state switching device. This relay has a normally open contact RL2.1 in shunt across the surge resistor 31. A tap 33 on the auto-transformer is connected, via contact RL2.2 of relay RL2 and, in series therewith, to the junction between the relay contact RL3.2 and the main winding 12 so that, when RL2.2 and RL1.1 are closed, the main winding 11 is energised from a tapped portion of the auto-transformer 30.

When the contactor 21 is initially closed, as previously explained, the starter circuit is energised and the auxiliary winding 12 is energised through the series circuit comprising capacitors 22 and 23. Relay RL2 is a delayed action relay, typically a DC unit fed from a rectifier with an interposed resistor/capacitor delay network. The delay is some tens of milliseconds and is for the purpose of suppressig any surge current required for energising the auto-transformer 30. As soon as the relay RL2 operates, relay contact RL2.1 closes, thereby short-circuiting the surge resistor 31 and connecting the auto-transformer 30 directly across the mains supply leads 20, 16. The relay contact RL2.2 will also close so that the main winding 11 is energised from the tap on the auto-transformer via contacts RL2.2 and RL1.1.

During the period t_0 to t_1,, the motor accelerates to a major proportion of its final speed and during that time period what is known as the back e.m.f. in the two windings, increases. The current which flows into a motor winding is dependent on the difference between that voltage which can be measured at the terminal and the back e.m.f. in the winding. During the period t_0 to t_1 the difference between the voltage on the terminal of the auxiliary winding, shown in Fig. 2a, and the back e.m.f. in the auxiliary winding is substantially constant and the auxiliary winding current, as shown in Fig. 2b, is, hence, substantially constant. During the same period of time, the difference between the voltage at the terminal of the main winding and the back e.m.f. in the main winding, decreases until at time t_1 said difference is zero and hence the current in the main winding decreases to zero, as shown in Fig. 2b. It is therefore convenient to determine V_2 as that voltage at the terminal of the auxiliary winding when the main winding current becomes zero and hence to select a relay RL1, which operates at the determined V_2 or to select a relay RL1, which operates at a voltage lower than the determined V_2 and to place in series with the coil of the relay a resistor which is so chosen that the relay operates when a voltage V_2 is applied across the resistor and the relay coil in series. If t_1 is delayed beyond the point when the main winding current becomes zero, the current in the main winding can be considered as reversing and current flows from the main winding. That t_1 might be delayed does not impair the effectiveness of the circuit, but it does not serve any useful purpose.

During the period t_0 to t_1' the total current taken from the supply, shown in Fig. 2e, is the sum of the auxiliary winding current and the current flowing in the primary of the transformer being the main winding current divided by the transformer ratio which might typically be 2. Hence the total current taken from the supply, where the transformer ratio is 2, is the sum of the auxiliary winding current and half the main winding current. Visually, Fig. 2e may not seem to be such, but it is so because of the relative phase angles of the two currents, which is not visually readily taken into account. It has been said that the total current taken from the supply is the sum of two currents, one of which is that which flows through the transformer. If the main winding is connected directly to the supply let the main winding starting current be then I. When a transformer of ratio two is interposed between the supply and the main winding the voltage at the terminal of the main winding is half the voltage of the supply and the main winding starting current is $I/_2$. That current of $I/_2$ flows in the transformer and because the ratio of the transformer is 2 then the associated current taken from the supply is I/4. The total supply current is hence the sum of the auxiliary winding current and I/4. This current is much less than if the main winding was connected directly to the main supply because the total supply current would then be the sum of the auxiliary winding current and I. At time t1 relay RL1 operates so closing contact RL1.2 and energising relay RL3. The closing of contact RL3.1 connects the main winding 11 directly to supply line 20 whilst opening of contact RL1.1 disconnects the main winding from the auto-transformer 30. It would be possible for the starter relay RL1 to disconnect the main winding 11 from the auto-transformer 30 and, by means of another contact on that relay, to connect the main winding 11 directly to the supply line 20. The relay RL1 could also be used in these circumstances also to disconnect the second capacitor 23. Such an arrangement would obviate the need for the relay RL3. However this arrangement can give rise to hunting of the contacts of RL1 as the voltage across the auxiliary winding 12 attempts to stabilise. Furthermore voltage disturbances could occur due to out-of-phase voltage disturbances could occur due to out-of-phase voltage conditions between the supply line 20 and the main motor winding 11. In the preferred arrangement illustrated therefore a relay RL3 is employed and the mechanical unloader 18 is operated through the normally closed contact RL3.3 of the relay RL3. Thus the motor starts against a low load. The

motor starts and begins to increase in speed. The circuit arrangement is such that the total current drawn is approximately equal to the normal full load current. At time t1, as previously described, the relay RL1 operates. This closes contact RL1.2 so operating the delay relay RL3 at a time t2 after the time t1.

During the interval between t_1 and t_2, the back e.m.f. in the main winding increases to the full line voltage. This is so because the motor is being driven by the auxiliary winding current which, through the complex nature of electromagnetic induction between the rotor and the windings of electrical machines, induces said back e.m.f. During said interval the main winding current is zero. At time t_2 the back e.m.f. in the main winding is very nearly equal to the supply voltage in both magnitude and phase angle. Closing of contact RL3.1 thus connects the main winding 11 to the supply line 20 with minimum voltage disturbance. Contact RL3.2, which is arranged to break after RL3.1 makes, disconnects the boost capacitor 23. Contact RL3.3 opens and the mechanical unloader 18 operates to increase a load on the motor. The total current builds up slightly to the new normal running current as shown in Fig. 2d whilst the auxiliary winding current decreases, as shown in Fig. 2b, because of the disconnection of the boost capacitor 23.

Although the circuit has been described with electromechanical relays, it is readily possible to use semi-conductor switching components with delay circuits which can readily be adjusted to suit the appropriate load on the motor.

In the above-described embodiment, an auto-transformer is used to reduce the voltage initially applied to the main winding. It would alternatively be possible to energise the main winding through a series resistor which is shorted out when the full voltage is to be applied; in such a case however the starting characteristics are not so satisfactory. In a typical case, the ratio of starting current to full load current is 4.5 to 1 for a direct start circuit, 2 to 1 for a resistance soft start and 1 to 1 for a transformer soft start circuit such as has been described above.

Another construction of starting circuit is illustrated in Fig. 3. In this figure, the same reference numerals are used as in Fig. 1 to indicate corresponding components. Fig 3 has two relays RL1 and RL2 and the figure shows their contacts in the positions immediately after switch on. Each contact is indicated by a series of three symbols, e.g. 2/3/NC. The first symbol is the relay number, e.g. RL2; the second symbol is the number of the contact on that relay, e.g. contact 3 and the third symbol indicates whether the relay contact is normally closed (NC) or normally open, i.e. when the relay is unenergised. In Fig. 4 waveform (a) shows the supply current waveform (b) is the main winding current, waveform (c) is the auxiliary winding current, waveform (d) is the auxiliary winding voltage and waveform (e) is the main winding voltage. These waveforms are oscillograms obtained during the starting period.

In the following description of Fig. 3, reference will be made only to the distinctive features of this circuit. The main distinction is the provision of a thermistor 40 which is connected in series with the main winding during a short part of the starting period. A change-over contact 1/1 of relay RL1 at time t_1 switches the thermistor in series with the winding 11 and later, at t_2, the thermistor is short-circuited by a contact 2/1/NO of relay RL2. The solenoid 17 for the compressor unloader valve 18 is connected in series with a contact 2/3NC of relay 2. Relay RL2 is energised via a time delay 41 and a contact 1/2/NO of relay RL1. The ratio of the transformer 30 is chosen in accordance with design requirements but typically would be in the region of 2 to 1. In a motor for driving a refrigerator compressor, the transformer ratio and the time delay between t_1 and t_2 can be selected to match the requirements of a particular compressor and the conditions at the compressor during starting.

The operation of the circuit of Fig. 3 is as follows:—

When the contactor 21 is closed, current flows into the auxiliary winding 12 via its capacitors 22 and 23 and into the main winding 11 via the transformer 30. The waveforms of the two currents are shown in Figs 4b for the main winding and 4c for the auxiliary winding. The starting current, Fig. 4a, is the sum of the auxiliary winding current, and , for a 2 to 1 transformer, half the main winding current. The latter current, before being reduced by the transformer, is already reduced (compared with a direct current) because of the low voltage applied to the main winding.

During the first phase after switching on, the voltage across the main winding 11 is substantially constant being the transformer secondary voltage, but the voltage across the auxiliary winding 12 has a rising profile and is a good indicator of motor speed. In many conventional start circuits the rising voltage on the auxiliary winding is used to operate the relay that opens the start capacitor circuit when the motor is at speed. In the transformer soft start circuit of Fig. 3, the auxiliary winding voltage is used to start the switching sequence.

As the motor accelerates the back e.m.f. in the main winding increases and at some time, t_1, is equal to the transformer terminal voltage. If the motor accelerates further, without some action being taken, then the main winding e.m.f. increases beyond the transformer voltage. Consequentially the main winding 11

starts to generate and current flows from it. During such a period the motor would be driven from the auxiliary winding 12. No harm would be caused, but nothing useful is gained by allowing the main winding to generate.

At point t_1 the transformer has served its purpose and the time is near when it should be removed from circuit and the main supply switched onto the main winding. However, point t_1 is not appropriate for putting the motor on line because of the large difference at that point between the supply voltage and the main winding e.m.f. Switching at t_1 would cause a large surge current to flow defeating the whole purpose the first phase of the start. Hence the main winding e.m.f. has to be allowed to rise to a larger value than it has reached at t_1 before the supply is closed onto the main winding. This is achieved in the following way.

Relay RL1 across the auxiliary winding has a change-over contact 1/1 in series with the main winding. RL1 is so chosen that its operating voltage is similar to that of the auxiliary winding at t_1. Some latitude is available. A resistor can be put in series with the coil of the relay to increase the operating voltage to the required value it required. At t_1 RL1 operates to disconnect the main windng from the auto-transformer. The motor continues to accelerate driven by the auxiliary winding. The operation of the change-over contact now connects the main winding to be fed from the mains supply through thermistor 40 so that a small current flows in this winding. During acceleration in phase two, the back induced e.m.f. in the main winding increases. In due course a point t_2 arrives at which, the main winding e.m.f. reaches a maximum and is similar to the supply voltage. At t_2 or a later point, the supply can be closed onto the main winding without a surge and the rest of the switching completed. In order to effect the precedure above, a second contact 1/2/NO of RL1 is used to initiate a time-delay relay RL2. The latter relay operates after a predetermined time to close the supply onto the main winding, to open-circuit the starter capacitor, and to close the solenoid valve. The delay unit 41 shown in Fig. 3 is diagrammatic. The delay may be achieved by driving RL2 from an RC circuit and bridge rectifier.

If the thermistor 40 was not provided, the main winding 11 would be open-circuit until time t_2. Just before contact 2/1 closes the voltages on its two sides, each with respect to neutral are similar in magnitude if t_2 is chosen correctly. Nonetheless the two voltages can be different in phase and some 80 volts could be present across 2/1 when it closes. The current on closing 2/1 could have unwelcome high peaks when compared with the low current of the first and second phases and the means to prevent it are as follows.

Contact 2/1 is connected in series with the normally open part of change-over contact 1/1 and the thermistor 40 is connected in parallel with contact 2/1. When contact 1/1 operates to disconnect the transformer 30 from the main winding, current flows from the supply, through the thermistor 40 to the main winding. As the thermistor temperature rises its resistance falls and the small main winding current brings the voltage across contact 2/1 to an acceptably small value before contact 2/1 is closed. It is acceptable, as described, to energise the thermistor at t_1.

No additional time delay circuit is necessary. Between t_1 and t_2 the main winding current is smaller than the auxiliary winding current and is not particularly useful for driving the motor. During the interval between t_1 and t_2 the motor is accelerated by the auxiliary winding current in the manner described earlier. Consideration of the waveforms of Fig. 4 illustrate the operation of the circuit at t_2.

CLAIMS

1. A starting circuit for a single phase induction motor having a main winding and an auxiliary winding with capacitor means in series with the auxiliary winding to provide a current therethrough on energising the starting circuit, wherein there are provided circuit means operative on starting the motor to reduce the voltage on the main winding to a lower magnitude than the normal running voltage, with switch means operative to apply the full voltage to the main winding as the motor runs up to speed.

3. A circuit as claimed in claim 1 wherein means are provided operative on starting the motor to disconnect to reduce the load on the motor until the full voltage is applied to the main winding.

3. A circuit as claimed in either claim 1 or claim 2 wherein the circuit means for reducing the voltage applied to the main winding comprises a transformer or auto-transformer for energising the main winding with switch means to switch out the direct energising circuit from the mains until the motor runs up to speed.

4. A circuit as claimed in either claim 3 or claim 4 wherein said transformer or auto-transformer has a turns ratio (voltage step-down) greater than unity.

5. A circuit as claimed in either claim 3 or claim 4 wherein said switch means to switch out the direct energising circuit comprises and electro-mechanical relay responsive directly or indirectly to the voltage across the auxiliary winding.

6. A circuit as claimed in either claim 3 or claim 4 wherein said switch means to switch out the direct energising current comprises solid-state switching means responsive directly or indirectly to the voltage across the auxiliary winding.

7. A circuit as claimed in any of claims 3 to 6 wherein said switch means operative to switch out the direct energising current comprises a relay responsive to the voltage across the auxiliary winding and arranged to disconnect the main winding from the transformer and to energise a further relay which operates, after a delay, to connect the main winding to the mains supply and to connect the mechanical load to the motor to be driven thereby.

8. A circuit as claimed in claim 7 wherein said further relay is also arranged to disconnect a capacitor in series with the auxiliary winding.

9. A circuit as claimed in any of claims 3 to 6 wherein said switch means is operative to apply the full voltage to the motor through a series thermistor and wherein means are provided operative to short-circuit the thermistor after a delay.

10. A circuit as claimed in claim 9 wherein said switch means is a change-over contact on a relay responsive to the voltage across said auxiliary winding.

11. A circuit as claimed in either claim 9 or claim 10 wherein the means operative to short-circuit the thermistor comprises a further relay with a delay circuit.

12. A circuit as claimed in claim 11 wherein said further relay also connects or initiates connection of the mechanical load to the motor to be driven thereby.

13. A circuit as claimed in any of claims 3 to 12 wherein said switch means to switch out the direct energising circuit comprises means responsive directly or indirectly to the voltage across the auxiliary winding and arranged to operate when or after the current in the main winding decreases to zero.

14. A circuit as claimed in any of claims 3 to 13 wherein said transformer is an auto-transformer with its winding, in series with a surge prevention resistor, connected across the power supply input.

15. A circuit as claimed in claim 14 and having a delayed operation switching device responsive to the voltage across the auto-transformer and operative to short-circuit the surge resistor after a short delay.

16. A circuit as claimed in claim 15 wherein said delayed operation switching device is arranged to complete the circuit for energising the main winding from the auto-transformer at a short time after the auto-transformer is energised.

17. A circuit as claimed in any of claims 1 to 8 wherein said switch means operative to apply full voltage to the main winding as the motor runs up to speed comprises a delayed action solid-state or electro-mechanical relay controlled by a contact on switching means responsive to the voltage across the auxiliary winding.

18. A circuit as claimed in claim 17 as appendant to claim 2 wherein said solid-state or electro-mechanical relay is arranged, when operated, to reconnect or restore the load to the motor.

19. A starting circuit for a single phase induction motor substantially as hereinbefore described with reference to Figs. 1 and 2 or Figs. 3 and 4 of the accompanying drawings.

20. A single phase induction motor having a starting circuit substantially as hereinbefore described with reference to Figs. 1 and 2 or Figs. 3 and 4 of the accompanying drawings.

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